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for

ANALYSIS OF PLASMA MEASUREMENTS FOR THE GEOTAIL MISSION

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Research Activities: 1 October 1993 through 30 September 1994

Data Processing

The Comprehensive Plasma Instrumentation (CPI) on board the Geotail spacecraft consists of three plasma analyzers: (1) a Hot Plasma analyzer to provide three dimensional sampling of the velocity distributions of magnetospheric electrons and ions, (2) a complementary Solar Wind analyzer to provide high resolution of energies and angles necessary to characterize cool streaming ion plasmas of the solar wind and the magnetosheath, and (3) an Ion Composition analyzer to identify ion species. The telemetry from this instrumentation is received at the University of Iowa on compact disks provided by the Central Data Handling Facility (CDHF) at Goddard Space Flight Center. With the use of calibrations and computer algorithms developed by the research staff at the University of Iowa the telemetry is then processed to produce computer files and graphical output suitable for scientific analysis.

Routine processing includes the production of color spectrograms that display the directional intensities of the plasmas. The spectrograms are the primary data product for initial surveys of the measurements. Operation of the plasma instrumentation is nearly continuous, and spectrogram production is an ongoing effort. During the period covered by this report spectrogram production was completed for all measurements through 31 May 1994.

The measurements are also used to compute quantitative plasma parameters, i.e., the plasma number density, bulk flow velocity, temperature, and pressure. Plasma parameters are computed for selected time periods to support research projects initiated by researchers at the University of Iowa and at other institutions. It is anticipated that continuous sets of plasma parameters will be eventually computed for the entire Geotail mission. At present, parameters from the Solar Wind analyzer have been computed for all measurements through 15 July 1994 and parameters from the Hot Plasma analyzer have been computed through August 1993. In addition, a set of software that computes CPI plasma parameters has been provided to the CDHF for the production of Key Parameter files that are made available to the research community.

The development of specialized analysis software has also continued during the past year. This work is a critical element of the analysis and is essential for the accomplishment of most research objectives. Computer programs are created as needed for tasks related to specific investigations. However, many of these specialized programs become tools that find more general application. For example, programs that merge magnetic field measurements from the Geotail magnetometer with the plasma measurements provide the capability to compute sophisticated parameters such as the beta of the plasma. The software that manipulates the field measurements is also merged with software developed to graphically display the three-dimensional velocity distributions of the plasmas. This last capability is critical in many investigations of physical plasma processes and has been used successfully in collaborative investigations with members of the PWI team led by H. Matsumoto.

Research Efforts

The CPI plasma measurements from the Geotail spacecraft are currently used by a number of scientists in support of varied research projects. In the course of this year research results have been presented at the 1993 Fall Meeting and the 1994 Spring Meeting of the American Geophysical Union; the International Conference on Substorms-2, Fairbanks, Alaska; the Chapman Conference, San Diego, CA; the Eighth International Symposium on Solar Terrestrial Physics, Sendai, Japan; and at the 30th COSPAR Scientific Assembly, Hamburg, Germany. A series of papers has been submitted for publication in peer-reviewed journals including several accepted for a special issue of Geophysical Research Letters dedicated to results from the Geotail mission. A list of presentations and publications is appended to this report. This list includes reports on research led by CPI investigators at the University of Iowa, by CPI Co-Investigators at other research centers, and reports produced in collaboration with scientists associated with other Geotail instrument teams. A summary of some of the research now in progress using CPI plasma measurements is given below.

Measurements from the CPI Hot Plasma Analyzer have been processed to compute one-minute averages of plasma densities, temperatures, and velocities for a substantial part of the Geotail deep tail mission. These parameters are used in a preliminary survey of the magnetotail for geocentric radial distances 10 to 210 Earth radii. Average parameter values and the range of parameter values are given for the center of Earth's magnetotail. The survey characterizes hot plasmas in the plasma sheet and cold plasmas in the vicinity of the plasma sheet. This work includes the thermal ion plasmas for which observations in this range of distances previously had been unavailable. One unanticipated result is the pervasive observation of cold tailward-streaming plasmas within the distant magnetotail. The source of these plasmas appears to be primarily the solar wind. Entry into the magnetotail occurs either at the nose of the magnetosphere or along the flanks. The evolution of cold streaming plasmas subsequent to magnetotail entry is now being researched by CPI Co-Investigator G. Siscoe and his colleagues at Boston University.

The cold plasmas within the magnetotail drift towards the midplane and are thought to be a principal source for the hot plasma sheet. A remarkable result from Geotail is the observation of cold ion beams coexisting as distinct components in the presence of hot plasma-sheet plasmas. Previously, such complex non-Maxwellian distributions with hot and cold components had been observed only during the magnetotail traversal of the Galileo spacecraft. Cold ions that encounter the distant X line or the neutral sheet at the center of the plasma sheet are accelerated and eventually may be heated or isotropized. The cold ions in the distant plasma sheet observed with CPI appear to be cold source plasmas at an early stage of this processing. Eventually these ions may become part of the hot isotropic plasma sheet near Earth, or may be ejected as streams into the plasma sheet boundary layer. However, the physical processes that lead to the development of these regions are not well understood. Interpretation of the Geotail observations in terms of nonadiabatic particle motion is proceeding in collaboration with the theory group at UCLA led by M. Ashour-Abdalla. This work is expected to contribute to our understanding of the formation of the plasma sheet and its boundary layer.

The development and evolution of plasmoids is a topic of considerable interest in studies of the magnetotail and of magnetospheric substorms. The standard model of a plasmoid pictures a disconnected magnetic island filled with hot plasmas that is expelled from the magnetotail as one part of the process of magnetic substorms. Previous observations of plasmoids in the distant tail did not include measurements of the thermal ions which are essential for a complete understanding of the plasma dynamics. A number of possible plasmoids have been identified in the Geotail data set by D. Fairfield at GSFC based upon reversals of the Z component of the magnetic field as observed with the Geotail magnetometer (MGF). An intensive study of the electron and ion velocity distributions and the plasma parameters for several of these events reveals unexpected features. Within the region of the plasmoid, as identified from the magnetic signature, the electrons are counterstreaming along the magnetic field indicating that these particles are trapped in a closed or mirroring magnetic topology. However, the ion distributions are found to be complex with separate hot and cold components. The bulk velocities of the electrons and the hot ions are the same, but the cold ions have lower speeds. Thus the bulk speed of the electrons is different from the bulk speed of the combined cold and hot ions, and an electric current must exist. The current is consistent with the large dawn-dusk component of the magnetic field that is observed in these cases. This transverse field seems to be a common feature of plasmoids, but is not accounted for by the standard model of comoving ions and electrons trapped in a magnetic island. The plasma and the magnetic field measurements from Geotail suggest that many of the cases identified as plasmoids may be more akin to magnetic flux ropes aligned along the dawn-dusk axis. Geotail provides an excellent in-situ laboratory for study of the development and evolution of these objects which also are known to exist in interplanetary space. We are currently working with R. Lepping at GSFC who finds that model flux-rope topologies compare well with the observations. Eventually, this work may modify and improve our understanding of the substorm process.

The topology of the magnetotail with its various regions and boundaries is determined by the complex interaction with the fields and plasmas of the solar wind. Magnetotail observations from Geotail and simultaneous solar wind observations from IMP 8 are reported by Frank et al., [1994] in a recent manuscript submitted to the Journal of Geophysical Research. These observations are presented in comparison with the results of a global time-dependent MHD simulation of the interaction between the solar wind and the magnetosphere. From the observations it is found that a rotation of the magnetic field in the solar wind is well correlated with repeated transitions at Geotail from the magnetotail lobe to a magnetosheath-like boundary layer. Using the solar wind magnetic field as input the MHD simulation accurately predicts these transitions. This work is remarkable because it provides the first substantial evidence that a global MHD model is capable of correctly predicting important aspects of the large-scale topology and dynamics of the magnetotail.

Collaborative work with several Geotail instrument teams and other researchers also is ongoing. Plasma measurements from CPI have been provided for use by scientists associated with the MGF, EFD, EPIC, and PWI instrument groups. Plasma parameters and spectrograms from the CPI Solar Wind and Hot Plasma analyzers are currently used by members of the Geotail MGF team led by S. Kokubun in their investigation of unusually large magnetotail magnetic fields and in a separate study of substorm timing that utilizes ground-based magnetic observations. Plasma measurements from CPI are used by H. Matsumoto and coworkers in comparison with PWI plasma wave measurements in their investigations of broadband electrostatic waves and Langmuir waves in the magnetotail, and chorus emissions and "barber-pole" emissions in the dayside magnetosphere. An investigation of coronal mass ejections and interplanetary shocks utilizing measurements from the CPI Solar Wind Analyzer is in progress at Kyoto University.

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